Internal Quarterly Report

Date of Report: 8th Quarterly Report-July31, 2020
Contract Number: 693JK31810001
Prepared for: DOT
Project Title: Improvements to Pipeline Assessment Methods and Models to Reduce Variance
Prepared by: GTI
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For quarterly period ending: July 31st, 2020

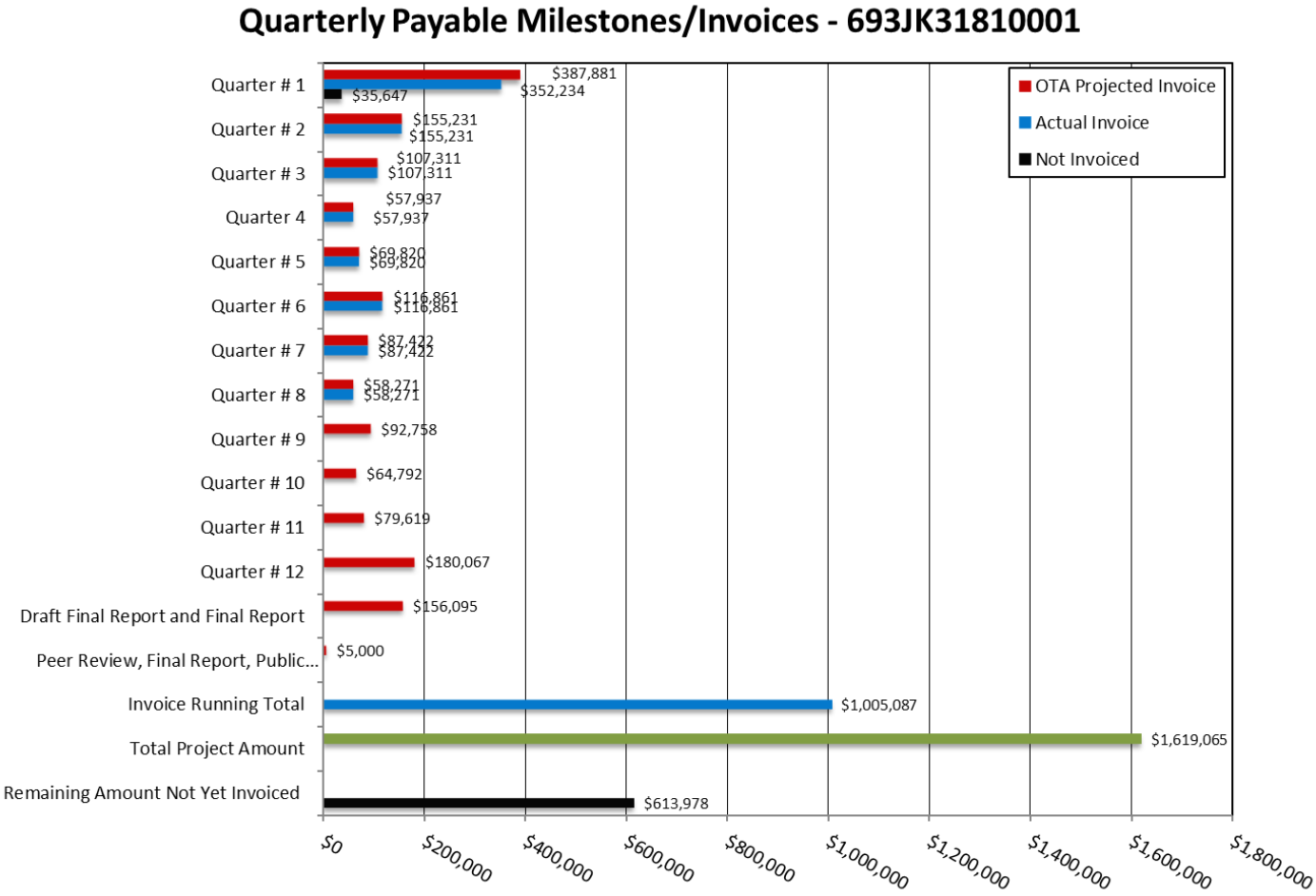
1: Items Completed During this Quarterly Period:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
54	3.2.2.4	Uncertainty Reduction	Probabilistic Fracture Assessment Phase 6 Report	8,345.00	$ -
55	3.3.1.2	Uncertainty Reduction	Integrated Variance Reduction and Bayesian Updating Phase 2 Report	10,000.00	$ -
56	4.2.4	Structural FEM Study	FEM DoE Phase 6 Report	15,505.00	$ -
57	5.2.2.4	FEM Simulation of NDE Signal Responses	Model-based Framework Phase 6 Report	10,000.00	
58	5.3.1.2	FEM Simulation of NDE Signal Responses	Learning and Data Fusion Phase 2 Report	10,501.00	
59	9.2.4	Project Management	8th Quarterly Report	3,920.00	$ -
54	3.2.2.4	Uncertainty Reduction	Probabilistic Fracture Assessment Phase 6 Report	8,345.00	$ -

2: Items Not Completed During this Quarterly Period:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
NA	NA	NA	NA	NA	NA

3: Project Financial Tracking During this Quarterly Period:



The invoice that will be submitted will include the following line items:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
54	3.2.2.4	Uncertainty Reduction	Probabilistic Fracture Assessment Phase 6 Report	$ 8,345	$ -
55	3.3.1.2	Uncertainty Reduction	Integrated Variance Reduction and Bayesian	$ 10,000	$ -
56	4.2.4	Structural FEM Study	FEM DoE Phase 6 Report	$ 15,505	$ -
57	5.2.2.4	FEM Simulation of NDE	Model-based Framework Phase 6 Report	$ 10,000	
58	5.3.1.2	FEM Simulation of NDE	Learning and Data Fusion Phase 2 Report	$ 10,501	
59	9.2.4	Project Management	8th Quarterly Report	$ 3,920	$ -
			Total	$ 58,271	$ -

4: Project Technical Status

The project technical work continues to progress as planned.

The focus in quarter 8 was to fully align the workflows of ASU, MSU and GTI.

- In quarter 6 we moved to using the same 3D models and the COMSOL Multiphysics modeling platform across all teams.
- In quarter 7 MSU began simulating the defects that ASU and GTI were working on
    - GTI running the structural FEM analysis
    - ASU performing the UQ analyses and dictating the next design point to run in order to minimize uncertainty across the analysis domain
    - MSU simulating MFL and Eddy Current techniques using COMSOL
- At the end of quarter 7 GTI and ASU discussed appropriate data analytics methods with the Principal Investigator of DOT contract 693JK31810003 "Validating Non-Destructive Tools for Surface to Bulk Correlations of Yield Strength, Toughness, and Chemistry" to determine how to best generate useful outputs for the industry from the combined results of these two projects
- The remaining 15 months of this project will be utilized to refine the useful data analytics within the context of the technical deliverables.
- Efforts will be made to streamline data transfer between the projects and investigators

The executive summary from each of the detailed task updates, that appear below, are pasted in this section for convenience.

Item # 54, Task # 3.2.2.4, Uncertainty Reduction, Probabilistic Fracture Assessment Phase 6 Report, Item # 55, Task# 3.3.1.2 Uncertainty Reduction, Integrated Variance Reduction and Bayesian Updating Phase 2 Report

This report summarizes the work done by ASU during the 8th quarter period, which is mainly focusing on the surrogate model construction to replace the time-consuming finite element model and uncertainty reduction using Bayesian entropy network method. The deliverables for Task 3.2.2.4 Uncertainty Reduction: Probabilistic Fracture Assessment Phase 6 and Task 3.3.1.2 Uncertainty Reduction: Integrated Variance Reduction and Bayesian Updating are completed.

Task 1 Surrogate model construction by active learning kriging model.
The probabilistic failure analysis usually requires a large number of performance functions which can be the time-consuming finite element model. In the project, the relative fine mesh grid is needed to obtain accurate structural responses while considering stochastic corrosion. To reduce the computational efforts, the numerical efficient surrogate model using the active learning kriging model is trained to replace the time-consuming finite element model. Among the countless uncertainties in geometries, loadings, material properties, random corrosion surface, five key factors that are sensitive to the system response are selected to be the surrogate model inputs. For outputs, the strain and stress at critical points are chosen for the further fracture model.

Task 2 Variance Reduction using Bayesian Updating.
Increasing amounts of data on engineering systems are available due to various sensor technology advancements. The data (or information) can be used to reduce the uncertainty in engineering models and optimize the management of systems. An effective framework for combining new information with existing models is provided using the Bayesian updating technique, in which prior probabilistic models are updated with data and observations. The Bayesian framework enables the combination of uncertain and incomplete information with

models from different sources and provides probabilistic information on the accuracy of the updated model. The updated information can then affect the probabilistic risk analysis results. Thus, the probabilistic fracture assessment in the project will be performed by both the probabilistic risk analysis and the Bayesian inference. In the real engineering problems, the additional formation may be available such as statistical moments (mean or variance, etc.) and range information. That information cannot be directly introduced into the Bayesian method. To combine additional information, a Bayesian Entropy Network (BEN) is used as a generalized information fusion tool to reduce the overall variance. This is a preliminary feasibility study and only synthetic examples are illustrated to show the methodology.

Item # 56, Task # 4.2.4, Structural FEM Study, FEM DoE Phase 6 Report

In Phase 6 of the FEM DoE task, GTI has continued to work in close collaboration with ASU to refine the workflow wherein multiple FEM simulations of given flaw combinations are performed in order to develop a surrogate model for fast probabilistic assessments. The developed workflow includes:

1. Execution of initial set of design-of-experiment (DoE) simulations,
2. Execution of supplemental simulations in parallel, based on ASU's active learning kriging algorithm,
3. Output of surrogate model.
4. Output of a FAD from the true stress-strain curve from GTI's steel model and FEA results.

GTI's work focused on executing simulations as part of ASU's active learning kriging algorithm, leveraging parallel execution of the simulations. Scatter in the simulations' stress responses at the crack tip was encountered which led to further detailed investigation of FEM mesh refinement. The root of the scatter was determined to be use of tetrahedral elements at the crack tip. A new meshing scheme was developed and successfully eliminated the crack tip scatter in stress response.
GTI plans to continue executing simulations of interacting defects under the GTI workflow utilizing ASU's active learning kriging algorithm. The process will be continuously refined as more experience is gained.

Item # 57, Task # 5.2.2.4, FEM Simulation of NDE Signal Responses, Model-based Framework Phase 6Report, Item # 58, Task 5.3.1.2, Learning and Data Fusion Phase 2 Report

In this report, stress corrosion cracking (SCC) has been investigated regarding NDE assessment since SCC is one of the predominant interreacting threats in pipeline steels, especially common when pipeline steels are exposed to humid environments. SCC simulation is motivated by the taking high resolution X-ray microtomography inspection results as a geometrical reference. On the other hand, inspection results of given pipeline by GTI is forward to data processing and analysis, different strength levels (init, t400, t900) are investigated.

The deliverables for Item #58 FEM Simulation of NDE Signal Responses, Model-based Framework Phase 6 Report are presented in the following sections:

- Introduction to SCC and Interacting Threats
- SCC Simulation

The deliverables for Item #59, Task 5.3.1.2, Learning and Data Fusion Phase 2 Report are presented in the following sections:

- Application of data processing on the given pipe geometry

- Mathematical formulation of data processing and its implementation
- Sub sampling rate and different performance metrics
- Results on the various crack defects

In this quarter we have studied the Stress Corrosion Crack, the physics behind it and we have simulated the SCC in COMSOL Thus we have studied the interacting threats. We have also studied how by varying sub sampling rates with much fewer number of MFL readings the defective areas are identified by kriging-based methods where the accuracy of the predicted algorithm is evaluated by various performance metrics. In the next quarter we will continue to study interacting threats along with study of uncertainty propagation by predictive density estimation.

Item # 53, Task # 9.23, Project Management, 7th Quarterly Report

All project management reporting requirements have been met.

5: Project Schedule –

All deliverables scheduled for completion in the eighth quarter were completed as scheduled.

End Project Status Update
